KATIHAR ENGINEERING COLLEGE, KATIHAR

CIVIL ENGINEERING, 3rd year (Semester - VI)

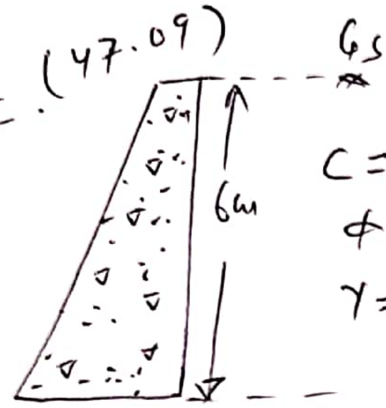
Subject: Soil & Rock Mechanics

Instructor: Prof. RASHID MUSTAFA

Set - B (Solution)

Q-1. (c)

Q-2 (47.09)

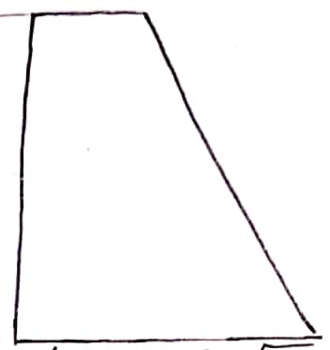


$c = 15\ kN/m^2$

$\phi = 25°$

$\gamma = 18\ kN/m^3$

$+2c\sqrt{K_p}$



$K_p \gamma H + 2c\sqrt{K_p}$

Passive earth pressure diagram due to c-ϕ soil

Passive Earth pressure at the top (p_p) $= +2c\sqrt{K_p}$

$= 2 \times 15 \times \sqrt{\frac{1+\sin 25}{1-\sin 25}}$

$= 47.09\ kN/m^2$

Q-3 (b) Direct shear test (Performed on sand)

Normal stress (σ_n) = $100\ kN/m^2$

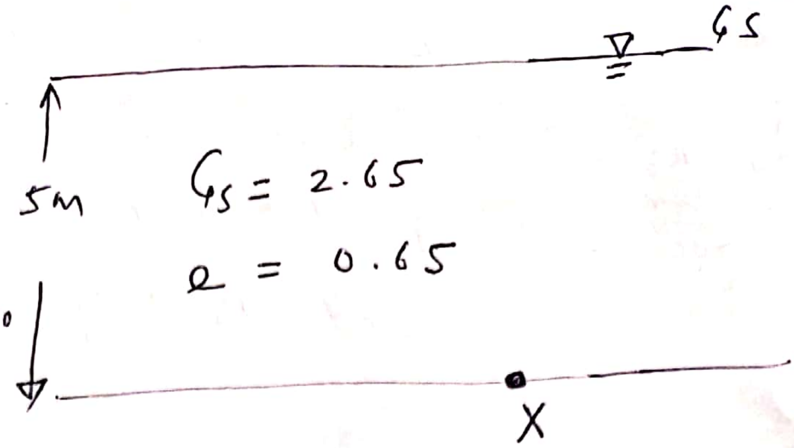
Shear stress (τ) = $50\ kN/m^2$

A/c to Mohr-Coulomb Eqn

$\tau = \cancel{c}^{\,0} + \sigma_n \tan\phi$

$\phi = \tan^{-1}\left(\frac{\tau}{\sigma_n}\right) = \tan^{-1}\left(\frac{50}{100}\right)$

$\phi = 26.565^\circ$



$G_s = 2.65$

$e = 0.65$

Saturated Density $(\gamma_{sat}) = \left(\frac{G+e}{1+e}\right)\gamma_w$

$= \left(\frac{2.65+0.65}{1.65}\right) \times 10$

$= 20\ kN/m^3$

Shear strength (τ_x) at X $= \sigma_n' \tan\phi$

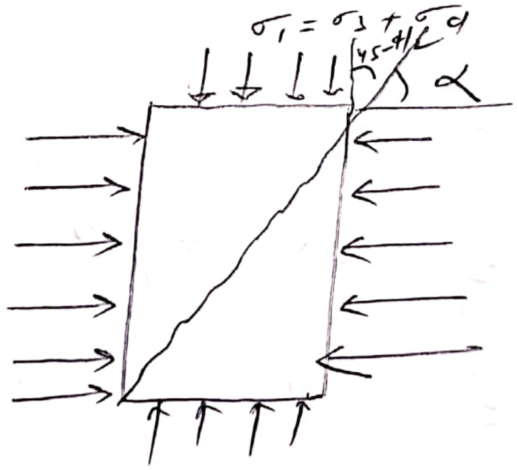
$= (20 \times 5 - 5 \times 10)\tan(26.565)$

$= 50 \tan(26.565)$

$= 25\ kN/m^2$

Closest answer is (b)

Q-4. (41°)



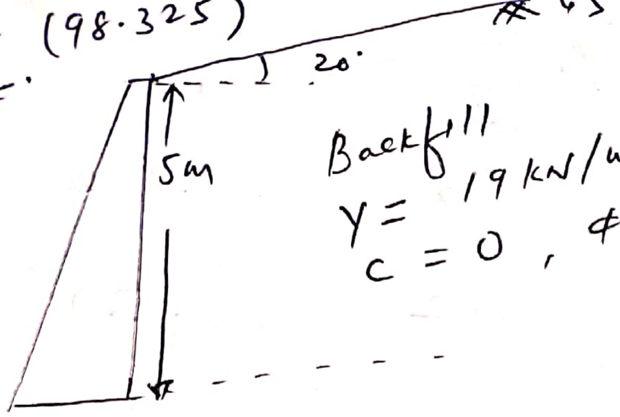
$c = 90\ kN/m^2$

Failure angle with major Principal Stress axis or Horizontal axis $= \alpha = 45 + \phi/2$

Failure angle with Vertical axis $(\alpha') = 45 - \frac{\phi}{2}$

$= 45 - \frac{8}{2} = 41^\circ$

Q-5. (98.325)



Backfill

$\gamma = 19\ kN/m^3$

$c = 0$, $\phi = 30°$

Active Earth Pressure Coefficient $(K_a) = \cos\beta \dfrac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$

$$K_a = \cos 20° \frac{\cos 20 - \sqrt{\cos^2 20 - \cos^2 30}}{\cos 20 + \sqrt{\cos^2 20 + \cos^2 30}}$$

$$= 0.414$$

Active Earth thrust at the base of the wall $(P_a) = \frac{1}{2} K_a \gamma H^2$

$$= \frac{1}{2} \times 0.414 \times 19 \times 25$$

$$= 98.325\ kN/m$$

Q-6. (c)

1 ✗

2 ✗

3 ✓

4 ✓

Q-7 (True)

Q-8 (0.057, 30.68)

Sr. No	Vertical load (kg)	Normal stress (N/mm²)	Proving ring reading	Shear stress (N/mm²)
1.	38.9	0.11	19	0.122
2.	149.6	0.41	47	0.30

Area (A) = $60 \times 60 = 3600 \ mm^2$

Normal stress (σ_n) = $\frac{\text{load}}{\text{Area}} \times 9.81 = \frac{38.9 \times 9.81}{3600}$

$= 0.11 \ N/mm^2$

Shear stress (τ) = $\frac{\text{Proving ring Constant} \times \text{Proving ring reading}}{\text{Area}}$

$= \frac{23 \times 19}{3600} = 0.122$

A/c to Mohr- Coulomb Equation

$\tau = C + \sigma_n \tan\phi$ [For First reading]

$0.122 = C + 0.11 \tan\phi$ —— (1)

$0.30 = C + 0.41 \tan\phi$ —— (2)

Operate (2) — (1)

$0.30 \tan\phi = 0.178$

$\phi = \tan^{-1}\left(\frac{0.178}{0.30}\right)$

$\phi = 30.68^\circ$

Scanned with CamScanner

From Eqn 1

$$C = 0.122 - 0.11 \tan(30.68)$$

$$C = 0.057 \ N/mm^2$$

Q-9. (0, 45.58°)

CD Test (saturated sand) → $\left[\begin{array}{l} \sigma_d = 250 \text{ kpa} \\ \sigma_3 = 110 \text{ kpa} \\ PWP(U) = 60 \text{ kpa} \end{array} \right]$

$$\sigma_1 = \sigma_3 + \sigma_d = 110 + 250 = 360 \text{ kpa}$$

$$\sigma_1' = \sigma_1 - U = 360 - 60 = 300 \text{ kpa}$$

$$\sigma_3' = \sigma_3 - U = 110 - 60 = 50 \text{ kpa}$$

$$\sigma_1' = \sigma_3' \tan^2\alpha + 2\cancel{c'}^{\,0} \cancel{\tan\alpha}$$

$$300 = 50 \tan^2\alpha$$

$$\tan^2\alpha = 6.0$$

$$\tan\alpha = 2.449$$

$$\alpha = \tan^{-1}(2.449)$$

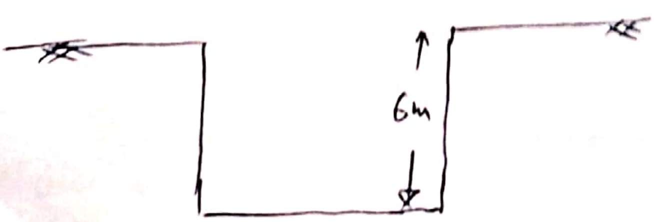
$$\alpha = 67.79$$

$$45 + \frac{\phi'}{2} = 67.79$$

$$\phi' = 45.58°$$

$$c' = 0$$

Q-10 (c)



Gs

$\gamma = 22\ kN/m^3$

$\phi = 30^\circ$

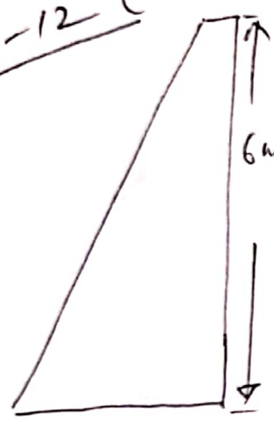
Unsupported height (H_c) $= \dfrac{4c}{\gamma\sqrt{K_a}}$

$$6 = \frac{4 \times c}{22 \times \sqrt{1/3}}$$

$$c = \frac{132}{4\sqrt{3}} = 19.05\ kN/m^2$$

Q-11. (b)

Q-12 (7.29, −24.6)

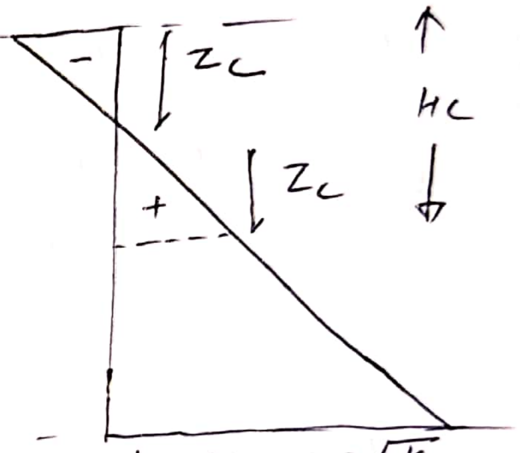


$\gamma = 19\ kN/m^3$

$c = 20\ kN/m^3$

$\phi_u = 30^\circ$

6m



$K_a \gamma H - 2c\sqrt{K_a}$

Active EP diagram for c-ϕ soil

Critical height (H_c) $= 2Z_c = \dfrac{4c}{\gamma\sqrt{K_a}}$

$$= \frac{4 \times 20}{19 \times \sqrt{1/3}} = \frac{80\sqrt{3}}{19}$$

$$= 7.29\ m$$

Total active thrust before tension crack (P_a) $= \displaystyle\int_0^H (p_a)\, dz$

$$= \int_0^6 (K_a \gamma z - 2c\sqrt{K_a})\, dz$$

$$P_a = \int_0^6 \left[\left(\frac{1}{3}\times 19\times z\right) - 2\times 20\times\frac{1}{\sqrt{3}}\right] dz$$

$$= \int_0^6 (6.33z - 23.09)\, dz$$

$$= 6.33\left[\frac{z^2}{2}\right]_0^6 - 23.09[z]_0^6$$

$$= -24.6 \text{ kN/m}$$

Q-13 (0, 29.63) UU test (Triaxial test for clay)

$H = 110$ mm , $\phi = 0$

$D = 55$ mm

deviator load (P_d) = 160 kN

Lateral strain (ϵ_L) = 12%

Cell Pressure (σ_3) = 110 N/mm²

$$A_c = \frac{A_0}{1-\epsilon_L} = \frac{\frac{\pi}{4}\times 55^2}{(1-0.12)}$$

$$= 2699.8 \text{ mm}^2$$

Deviator stress (σ_d) $= \frac{P_d}{A_c} = \frac{160\times 10^3}{2699.8} = 59.26 \frac{N}{mm^2}$

$$\sigma_1 = \sigma_3 + \sigma_d$$

$$= 110 + 59.26 = 169.26 \text{ N/mm}^2$$

$$\sigma_1 = \sigma_3 \tan^2\alpha + 2c\tan\alpha$$

$$169.26 = 110\tan^2(45+0) + 2c\tan(45+0)$$

$$c = \frac{59.26}{2} = 29.63 \text{ N/mm}^2$$

Q-14 (0.66)

$c = 60\ kN/m^2$

$\phi = 20°$

$\gamma = 19\ kN/m^3$

Over consolidation ratio (OCR) $= \dfrac{\text{Past overburden}}{\text{Present Overburden}} = \dfrac{95}{95}$

$= 1$ (Normally Consolidated)

$(K_0)_{NC} = 1 - \sin\phi$

$= 1 - \sin 20$

$= 0.66$

Q-15. (0.144)

When there is no movement of wall

$\Downarrow$

Earth Pressure at-rest Condition

$K_0 = 1 - \sin\phi$

$0.55 = 1 - \sin\phi$

$\sin\phi = 0.45$

$\phi = \sin^{-1}(0.45) = 26.74°$

$$\frac{K_a}{K_p} = \frac{\dfrac{1-\sin\phi}{1+\sin\phi}}{\dfrac{1+\sin\phi}{1-\sin\phi}} = \left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

$$= \left(\frac{1-\sin 26.74}{1+\sin 26.74}\right)^2 = 0.144$$

~~END OF SOLUTION~~

Q-16. In Taylor stability chart, the stability number is based on the assumption that factor of safety w.r.t friction angle is unity ($F_\phi = 1$). Thus effective angle is used in the chart and it is equal to the mobilised angle.

Q-17 (a)

$H = 20$ cm

$D = 10$ cm

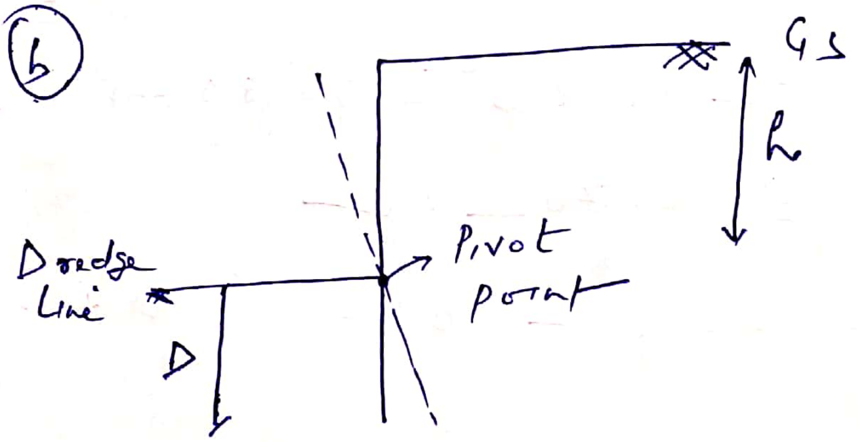
Torque $(T) = 1000$ kg-cm

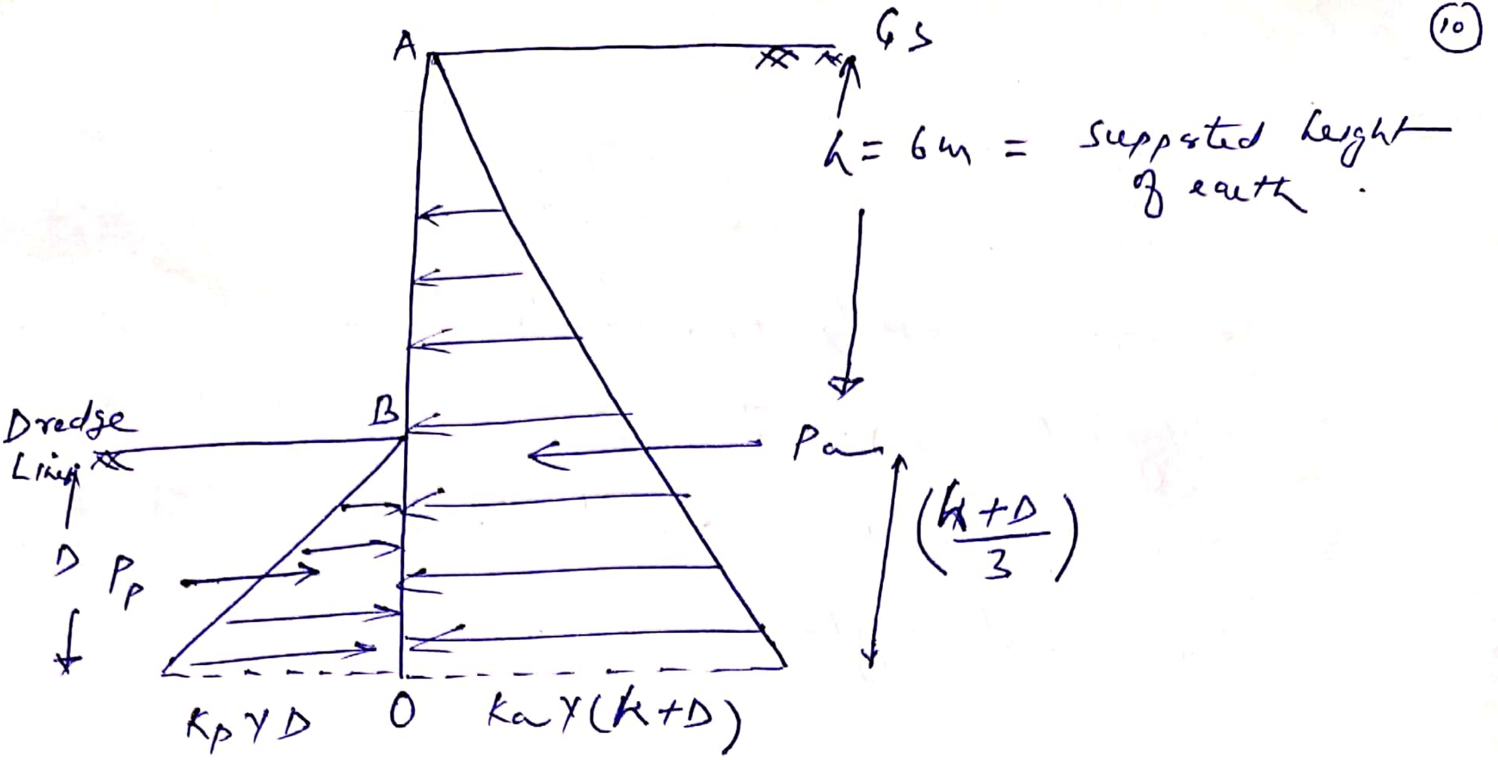
Cohesion (c) or Shear strength

$$= \frac{T}{\pi D^2\left(\frac{H}{2} + \frac{D}{6}\right)} = \frac{1000}{\pi \times 100\left(\frac{20}{2} + \frac{10}{6}\right)}$$

$$= \frac{1}{\pi\left(1 + \frac{1}{6}\right)} = \frac{1}{\pi} \times \frac{6}{7} \text{ kg/cm}^2$$

Q-18 (b)





Taking moment about O

$$\left(\frac{P_P}{FoS}\right) \cdot \frac{D}{3} - P_A\left(\frac{h+D}{3}\right) = 0 \quad \text{—} (1)$$

Where $P_P = \frac{1}{2} K_p \gamma D^2$

$P_A = \frac{1}{2} K_a \gamma (h+D)^2$

For $\phi = 35°$, $\gamma = 18\ kN/m^3$, $FoS = 2$, $h = 6m$

$$K_a = \frac{1 - \sin 35}{1 + \sin 35} = 0.271$$

$$K_p = \frac{1}{K_a} = 3.69$$

From (1)

$$\frac{\frac{1}{2} \times 3.69 \times 18 \times D^2}{2} \times \frac{D}{3} - \frac{1}{2} \times 0.271 \times 18 \times (6+D)^2 \times \frac{6+D}{3} = 0$$

$$1.574 D^3 - 4.878 D^2 - 29.268 D - 58.536 = 0$$

$$D = 6.702\ m$$

Depth of embedment (D) = 6.702 m

Q-19 (d.) Taylor stability Number (S_n)

$$\boxed{S_n = \frac{c}{F_c \cdot \gamma \cdot H}}$$

Where $c \rightarrow$ Cohesion

$F_c \rightarrow$ Factor of safety w.r.t Cohesion

$\gamma \rightarrow$ Unit weight of soil

$H \rightarrow$ Height of slope

Q-20 (a)

$\gamma_{sat} = 18\ kN/m^3$

$\phi' = 35°$, $\beta = 15°$

(i) When slope is completely dry or submerged but without seepage.

$$FOS = \frac{\tan\phi}{\tan\beta} = \frac{\tan 35°}{\tan 15°} = 2.61$$

(ii) When seepage occurs at and parallel to the surface of slope

$$FOS = \frac{\gamma_{sub}}{\gamma_{sat}} \cdot \frac{\tan\phi}{\tan\beta}$$

$$= \left(\frac{18 - 9.81}{18}\right) \frac{\tan 35}{\tan 15}$$

$$= 1.19$$